Exercise walk-through

Gauss's Law ▪ 8.6

eXercise

You must be able to

- state **Gauss's law 高斯定律**, $\oint \vec{E} \cdot d\vec{A} = \dfrac{Q_{\text{enc}}}{\varepsilon_0}$
- choose a **Gaussian surface 高斯面** whose symmetry makes $\vec{E}$ constant and perpendicular
- apply Gauss's law to spherical, cylindrical, and planar distributions
- explain why $\vec{E} = 0$ inside a conductor in electrostatic equilibrium

Method — Gauss's law

$\oint \vec{E} \cdot d\vec{A} = \frac{Q_{\text{enc}}}{\varepsilon_0}$: the net flux through a closed surface equals the enclosed charge divided by ε_0.

Method — Choose the symmetry

Pick a Gaussian surface (sphere, cylinder, box) on which E is constant and either perpendicular or parallel to the surface, so the integral becomes $E \times A$.

Method — A point charge

For a sphere of radius r around charge q: $E(4\pi r^2) = \frac{q}{\varepsilon_0}$, giving $E = \frac{kq}{r^2}$. Inside a conductor at equilibrium, no charge is enclosed, so $E = 0$.

Practice 2.1 ▪ 1 mark

State Gauss's law.

Solution 2.1

Worked steps

the net electric flux through a closed surface equals the enclosed charge divided by ε_0 **B1**.

Practice 2.2 ▪ 1 mark

State the electric field inside a conductor in electrostatic equilibrium.

Solution 2.2

Method: A point charge

Worked steps

zero **B1**.

Practice 2.3 ▪ 2 marks

A charge of 5.0×10^{-9} C is enclosed by a closed surface ($\varepsilon_0 = 8.85 \times 10^{-12}$). Find the flux through it.

Solution 2.3

Method: Gauss's law

Worked steps

$$\Phi_E = \frac{Q_{\text{enc}}}{\varepsilon_0} = \frac{5.0 \times 10^{-9}}{8.85 \times 10^{-12}} = 565 \text{ N m}^2\,\text{C}^{-1} \quad \textbf{M1}\ \textbf{A1}.$$

Exam-style 3.1 ▪ 1 mark

Gauss's law relates the flux through a closed surface to the

A total field everywhere

B charge enclosed

C surface area

D current

Solution 3.1

Method: Gauss's law

- **A** total field everywhere
- **B** charge enclosed ✓
- **C** surface area
- **D** current

Worked steps

B.

Exam-style 3.2 ▪ 1 mark

Inside a charged conducting sphere in equilibrium, the electric field is

A kq/r^2

B zero

C at its maximum

D infinite

Solution 3.2

Method: A point charge

A kq/r^2

B zero ✓

C at its maximum

D infinite

Worked steps

B.

Exam-style 3.3 ▪ 2 marks

A point charge $+8.0 \times 10^{-9}$ C sits at the centre of a spherical surface of radius 0.20 m ($\varepsilon_0 = 8.85 \times 10^{-12}$, $k = 8.99 \times 10^{9}$).

(a) Find the flux through the sphere.

(b) Find the field at the surface.

Solution 3.3

Method: Gauss's law

Worked steps

(a) $\Phi_E = \dfrac{Q}{\varepsilon_0} = \dfrac{8.0 \times 10^{-9}}{8.85 \times 10^{-12}} = 904 \text{ N m}^2\,\text{C}^{-1}$ **M1** **A1**. (b) $E = \dfrac{kq}{r^2} = \dfrac{8.99 \times 10^9 \times 8.0 \times 10^{-9}}{(0.20)^2} = 1.8 \times 10^3 \text{ N C}^{-1}$ **M1** **A1**.